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Structural Design and Analysis of Trump-world Marine

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Abstract

This paper introduces the structural design and analysis of the Trump-world Marine. As a residential development, this building is located at Haewoondae, Busan, Korea. It is comprised of 2 residential towers with 42 stories (137.8m-high) and 2 office towers with 30 stories. Towers are currently under construction. The structural system is a building system and composed of main core wall (Thk. 900~1100mm) and fin wall (Thk. 900mm). Most of all, it is the hot issue that the building resists big wind load in Busan which is face to sea. That's the why it has the thick wall thickness. Two topics are described in this paper. One is the study about the structural system considered the contribution rate of lateral resisting elements and resistance of the upward pressure of water by case studies and the other is a detail design and analysis of connection part at tie girder between upper wall and lower columns.

Keywords: Tall buildings, Structural System, Wind load

1. Introduction

It is gained the growth of the high-rise building, that the development of the structural analysis tools, materials, and construction technologies. And the high strength concrete can make a possibility of designing the Reinforced Concrete high-rise buildings. Therefore, the more RC high-rise buildings are currently being constructed in Korea.

Trump-world Marine is comprised of 2 residential towers with 42 stories (137.8m-high) and 2 office towers with 30 stories. Towers are currently under construction. The structural system is a building system and composed of main core wall (Thk. 900~1100mm) and fin wall (Thk. 900mm). Most of all, it is the hot issue that the building resists big wind load in Busan which is face to sea. That's the why it has the thick wall thickness.

Three topics are described in this paper.

First topic is the study about the structural system considered the contribution rate of lateral resisting elements.

Second topic is resistance of the upward pressure of water by case studies.

And the third topic is a detail design and analysis of connection part at tie girder between upper wall and lower columns.

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Fig. 1. Overview of Trump-world Marine

2. Building Outline

1) Outline

Trump-world Marine is composed of two residential buildings and two office buildings. It is located at Haewoondae, Busan in Korea. This area is near by sea therefore it has very strong winds.

In residential building, thickness 200~300mm shear wall resists gravity loads. And slab thickness is 160mm and 190mm.

And in office building, columns and perimeter girder resist gravity loads. And slab thickness is 200mm.
Because it has very bad bearing earth, it is used of pile foundation (diameter 1200mm, 1500mm, and 2000mm RCD pile) for building supporting.

Fig. 2. Site review

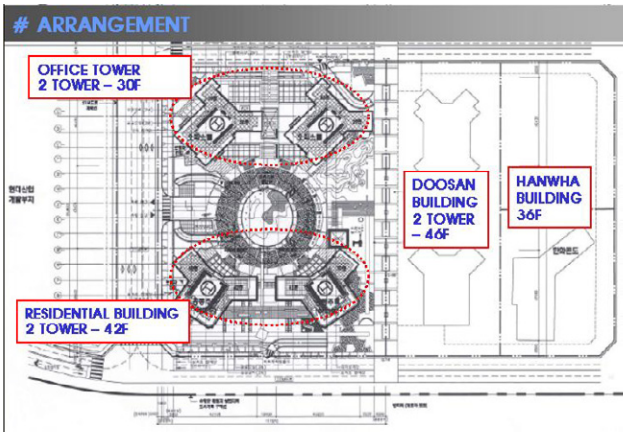


Fig. 3. Building arrangement

2) Materials

The concrete strength of the vertical members from 3rd underground to 10th above ground is 40MPa and 30MPa above 10th floor. 30MPa of concrete strength is used for the horizontal members.

3) Story Height

The Story Height of underground is 5.0m and 3.0m is for the typical floor of residential building. The overall height is about 140m. The 2nd and 3rd floor has transfer system. It is comprised of upper wall, tie girder and lower column. It is described detail analysis part.

3. Design Loads

1) Gravity Loads

Dead loads consist of the weight of all materials of construction incorporated into the building including but not limited to walls, floors, dealings, finishes, cladding and other similarly incorporated architectural and structural items.

Live loads are those loads by the use and occupancy of the building or construction loads.

2) Lateral Loads

It has very big wind load due to sea. Therefore wind load is larger than seismic load. Table 1 shows lateral load condition. As shown in the table 2, wind load is more critical than seismic load.

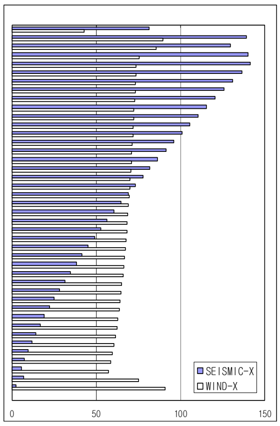
Table 1. Lateral Load condition

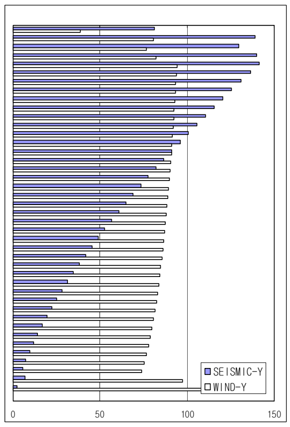
Lateral loads condition		
Wind load	- Basic Wind Speed	40m/s
	- Exposure Category	D
	- Importance Factor	1.1 (APT) 1.0 (Office)
Seismic Load	- Area Factor	0.11
	- Importance Factor	1.5 (APT) 1.2 (Office)
	- Response modification Coefficient factor	3.0 (APT) 4.0 (Office)

Table 2. Base shear comparison for lateral loads (APT)

Load	Wind Load	Seismic Load
X-dir	2895 tonf (103%)	2800 tonf (100%)
Y-dir	3610 tonf (129%)	2800 tonf (100%)

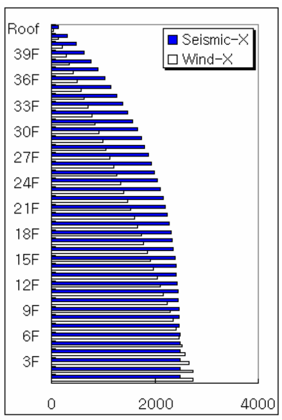
Table 3. Story force (APT)

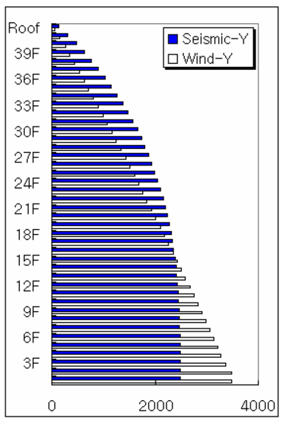




X-dir	Y-dir

Table 4. Story shear (APT)





X-dir	Y-dir

4. Plan review (Residential Building)

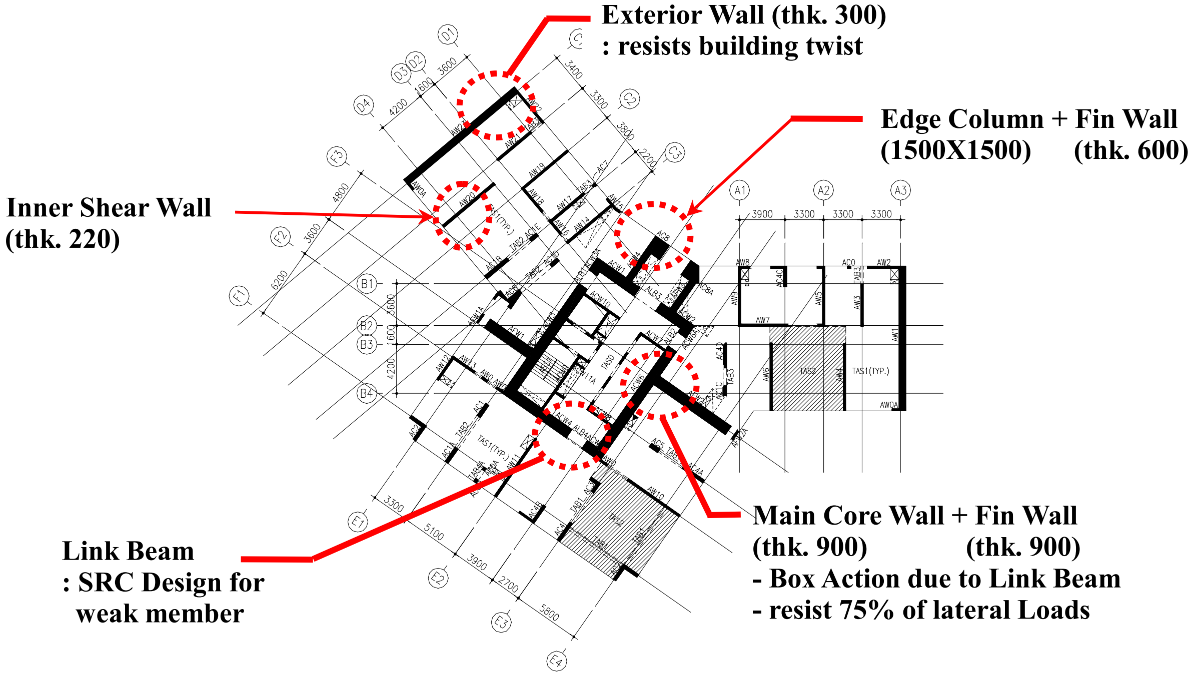


Fig. 4. Plan system of residential building

5. Structural Analysis for Residential Building

The most important thing for the high-rise building design is the decision of a lateral load resisting system. Normally the shear wall system is applied for resisting lateral loads in buildings lower than 40 stories, however this system is uneconomic for the high-rise buildings because it is flexible to resist lateral loads. Therefore, various lateral load -resisting systems are being applied as an alteration.

It is important thing that the study for relation of each lateral resisting elements and stiffness ratio.

Trump-world Marine has adopted the core wall, fin wall, and inner shear wall.

The study case for stiffness ratio of lateral resisting elements are as follows ;

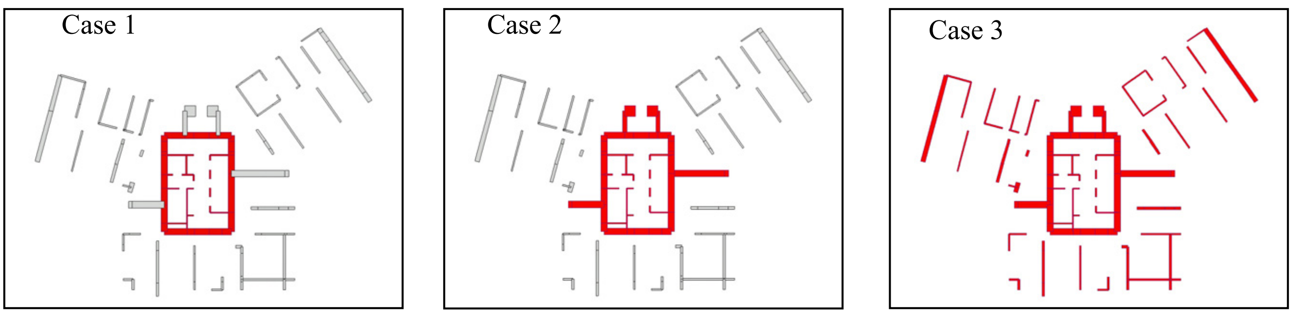
Case 1 : Core wall only
Case 2 : Core wall + Fin wall
Case 3 : Core wall + Fin wall + Inner wall

The stiffness in each has been compared by the results of displacement that is based on the core wall only system.

With considering the and crack section, here the 50% of stiffness in lintel beam has been applied.

	Case 1	Case 2	Case 3
Displacement (cm)	93	45.3	33.2
Stiffness Ratio K=1/displ.	100%	205%	280%

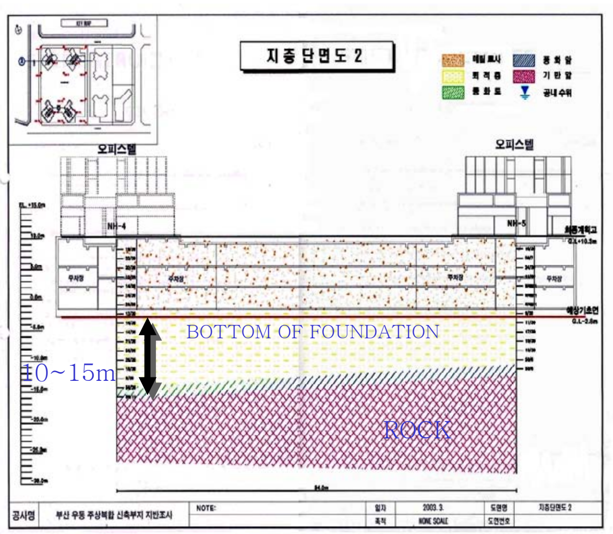
The case studies show that a core wall and fin wall is main lateral resisting system.(73% stiffness of total stiffness)



6. Foundation System

The depth between the soft rock and the bottom of foundation is about 10~15m. It is suitable to pile foundation for weak ground condition.

We use the RCD pile, which is cast in place concrete pile, for supporting the building.



7. The Prevention from Buoyancy

In this site, because it is located to near by sea, design groundwater level is used G.W.L ±0 in the consideration of overflow of water.

The method of the system prevented from buoyancy in the low storied part of the building is as follows.

Alt 1. P.H.C Pile + Rock Anchor
Alt 2. P.H.C Pile + Anchor Pile
Alt 3. R.C.D Pile + Drop

In the case of alt 2, anchor piles take over a portion of the tensile force. And in the case of alt 1, it is increased compression force to the pieces of P.H.C pile, because rock anchor piles do a portion of both the tensile force and compressive force. In the beginning of design, alt 2 is considered. But the method of alt 2 is expensive. Therefore, alt 3 is thrashed out.

Alt 3 is designed with R.C.D Pile with tensile capacity against buoyancy. The thickness of drop is secured thickness1500mm in order to the embedded length of bars used it. Besides, the thickness of footing slab is decreased from thickness 800mm (Alt 1, Alt2) to 700mm. Selected Alt 3 improve workability and reduce construction cost.

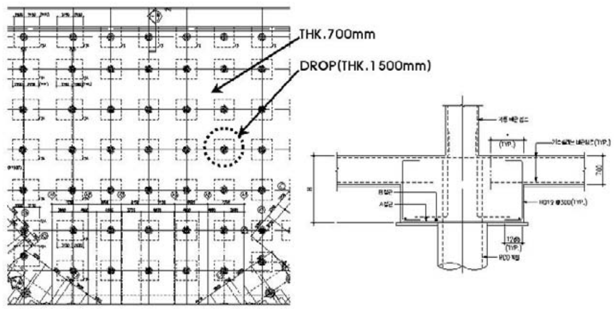
(a) ALT 1 : P.H.C. Pile + Rock Anchor

Piece of P.H.C. Pile		Piece of Rock Anchor (120 tf/EA)	Note
Φ400 (Ra=70tf/EA)	(660+120x4)/70 =16.3→17 EA	120 x 4 EA=480 >468 4 EA	For a module
Φ500 (Ra=100tf/EA)	(660+120x4)/100 =11.4→12 EA		

(b) ALT 2 : P.H.C. Pile + Anchor Pile

Piece of P.H.C. Pile		Piece of Rock Anchor (70 tf/EA, Tension Only)	Note
Φ400 (Ra=70tf/EA)	(660)/70=9.4 → 10 EA	468/70=6.7 → 7 EA	For a module
Φ500 (Ra=100tf/EA)	(660)/100=6.6 → 7 EA		

(c) ALT 3 : R.C.D. Pile + Drop



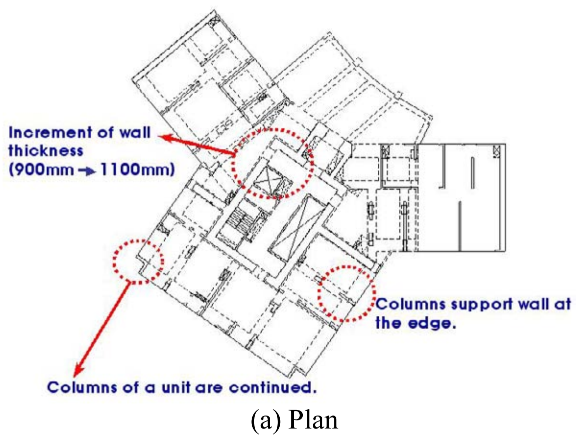
[Foundation plan] [R.C.D.Pile + Drop]

Fig. 5. Alternative about foundation system

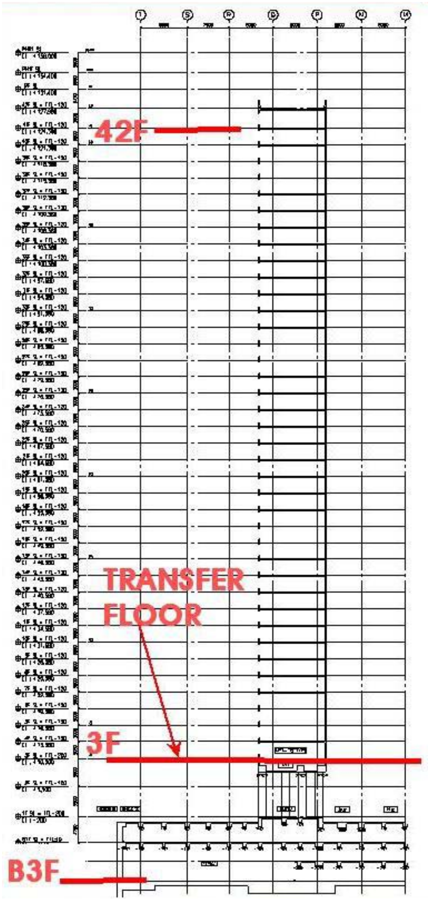
8. Transfer System

In the office towers, some columns of 30 stories are transferred at 1st floor. It is used the transfer plate or the transfer girder for a transfer systems. Generally it is well known, so it is omitted in this paper.

Besides shear walls are transferred to the moment frame with beam and girder at the 3rd floor of the residential towers as shown fig.6. Under the transfer floor columns are installed at both sides of shear wall. Tie girder of thickness 1200mm transfers 40 stories' shear wall. Columns of in the unit are continued to the foundation.



(a) Plan



(b) Elevation

Fig. 6. Section and plan of the transfer floor

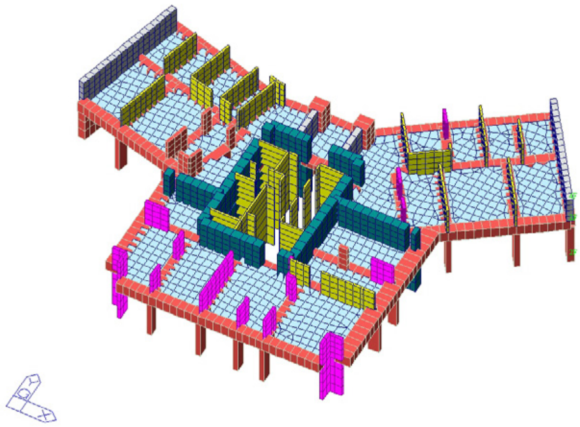


Fig. 7. A detailed model for the transfer floor

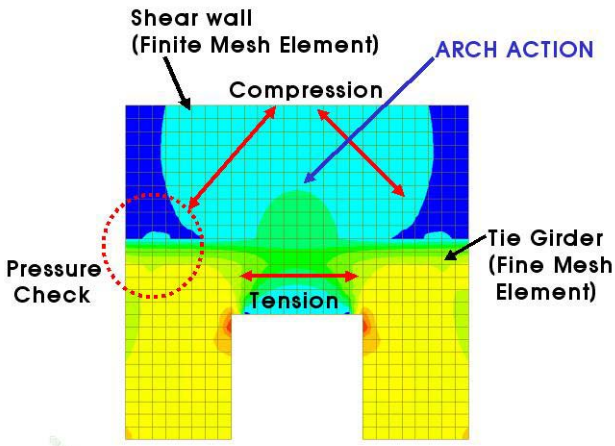


Fig. 8. Action mechanism of the transfer system

The transfer system with a tie girder is designed by an accurate finite element analysis using a fine mesh. Fig.7 shows the analysis model by this method. Fig.8 represents the stress mechanism of the transferred wall and the tie girder. Compression stress is occurred in the end of shear walls by arch action. And the tie girder gets tension stress. In addition to considering these actions, the pressure stress of a column and a wall must be checked.

Under the transfer floor thickness of core wall is increased from 900mm to 1100mm. It minimizes the stiffness irregularity by soft story and discontinuity in capacity by weak story.

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